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TESTS OF DYNAMICAL SUPERSYMMETRIES VIA CHARGED PARTICLE TRANSFER REACTIONS*

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ABSTRACT

We have investigated the (t,p) and $(\vec{t}, \alpha)$ reactions on enriched ^{191,193}Ir targets. The resultant spectroscopic strengths are compared and contrasted with the expectations of the dynamical supersymmetry scheme proposed for the Pt-Ir region.

INTRODUCTION

One of the most exciting developments in nuclear structure models has been the suggestion of Iachello that dynamical supersymmetries[1] may exist in nuclei. The first solution of the supersymmetric structure was obtained for coupling a $j = 3/2$ fermion to an O(6) boson core and was predicted[1] to occur in the Pt-Ir region where the even-Pt nuclei have been well described[2] as exhibiting the O(6) symmetry[3] of the IBA and Ir ground states have $J^{\pi} = 3/2^{+}$. The spinor representation for describing the structure of a particular nucleus in this region is Spin (6).

A schematic level diagram for the equivalent even- and odd-mass nuclei is shown in Fig. 1. The eigenvalue equation for the Spin (6) spectrum is given by[1]

$$E[N, (\sigma_1 \sigma_2 \sigma_3), (\tau_1 \tau_2), \nu_\Delta, J, M] = -\tfrac{1}{2}A[\sigma_1(\sigma_1 + 4) + \sigma_2(\sigma_2 + 2) + \sigma_3^{2}] + B[\tau_1(\tau_1 + 3) + \tau_2(\tau_2 + 1)] + C\,J(J+1) \qquad (1)$$

The quantum numbers are very similar to those obtained for O(6) boson spectra. N is the total number of bosons; σ_1 is similar to σ of O(6) with $\sigma_2 = \sigma_3 = 0(1/2)$ for even (odd) mass nuclei; τ_1 is analogous to τ of the O(6) limit, with $\tau_2 = 0(1/2)$ for even (odd) nuclei; and J is the total angular momentum with projection M. As in the case of O(6) nuclei, ν_Δ is necessary to uniquely identify states and is not important in determining transition probabilities, for example. Given the simple forms of σ_2, σ_3 and τ_2 (the additional Spin (6) quantum numbers that do not occur in the O(6) boson symmetry) eq. 1 reduces to the well-known O(6) eigenvalue equation for even nuclei. Since the character of the states is determined by σ_1 and τ_1, in Fig. 1, for simplicity, we have labeled states with σ, τ, and ν_Δ only.

The Spin (6) level scheme in an odd-mass nucleus is not a simple weak-coupling picture. An example is given by the first $\tau = 3/2$ multiplet which would seem to be analogous to coupling the $3/2^+$ ground state to the $2^+ \tau = 1$ state in the even core. However, weak coupling would give a 7/2, 5/2, 3/2, 1/2 multiplet; in the present case the 3/2 state is "missing", with the lowest $3/2^+$ state being of $\tau = 5/2$ character. In analogy to the 0^+ state of the traditional two-phonon triplet in the even nucleus being pushed up in energy to become the "band head" of the $\sigma < \sigma_{max}$ sequence, the "weak coupling" $3/2^+$ state becomes the "band head" of the first $\sigma < \sigma_{max}$ sequence in the odd nucleus.

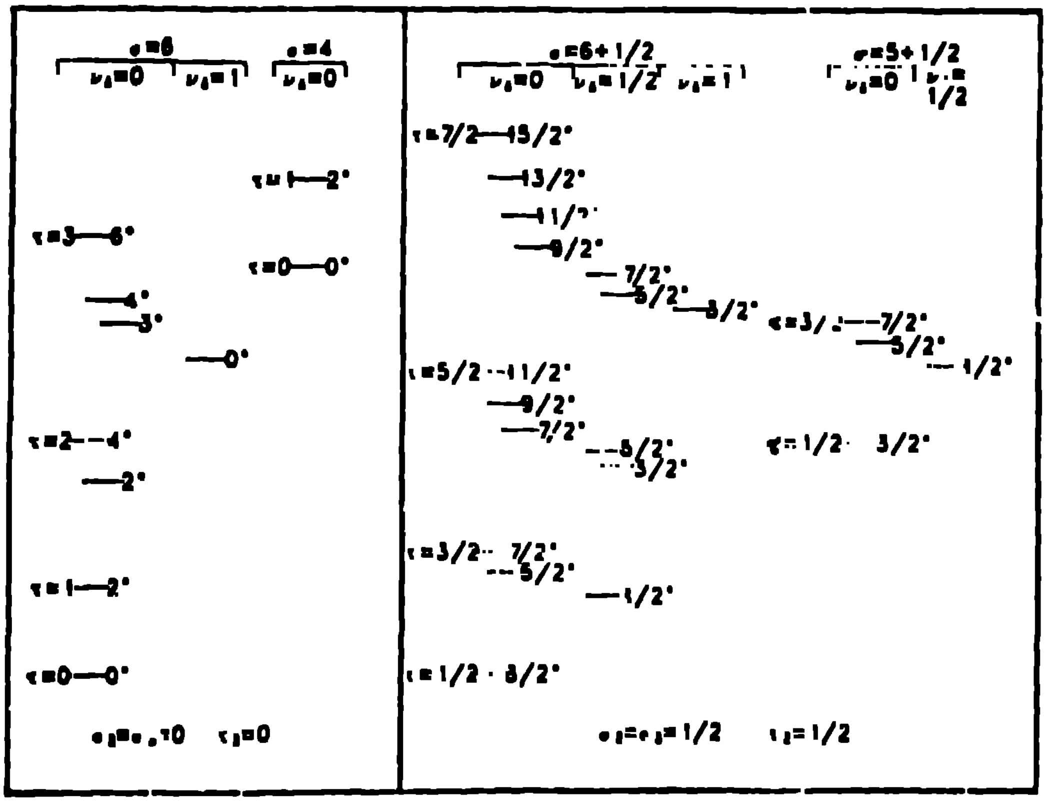

Fig. 1. Typical Spin (6) spectra for even and odd-mass nuclei.

CHARGED PARTICLE TRANSFER STRENGTHS

As in the case for the O(6) limit of the IBA (see Ref. 4, 5) there exist analytical expressions for two-neutron transfer strengths for supersymmetric systems. For Pt, Ir (t,p) reactions, where are investigating N→N-1, Iachello has obtained[1]

$$I^{even}(N\to N-1)= \alpha_\nu^2\,\frac{N_\nu(N+3)}{2(N+1)}\left(\Omega_\nu-(N_\nu-1)-\frac{(N-2)(N_\nu-1)}{2N}\right) \quad (2)$$

$$I^{odd}(N\to N-1)= \alpha_\nu^2\,\frac{N_\nu(N+4)}{2(N+2)}\left(\Omega_\nu-(N_\nu-1)-\frac{(N-2)(N_\nu-1)}{2N}\right) \quad (3)$$

where N, N_ν, and Ω_ν refer to the total number of bosons and the degeneracy of the shell as in eq. 4 of Ref. 4. In the Pt-Ir region where $N \approx 7$, eq. 2,3 predict essentially equal strengths for Ir (t,p) and Pt (t,p). As in O(6) nuclei no excited L = 0 strength would be observed.[4]

The experimental enhancement factors obtained from our present Pt, Ir (t,p) measurements[5,6] are summarized in Table 1 and are compared to the supersymmetry predictions. The agreement between the empirical and predicted strengths appears exceptional. However, problems do exist. As expected, essentially no excited L = 0 strength is observed in the ^{193}Ir (t,p)^{195}Ir reaction. However, two $3/2^+$ states above 1 MeV are strongly (8-15% of g.s. strength) populated in ^{193}Ir, possibly indicating the emergence of another degree of freedom. Comparing Ir (t,p) strengths to those in Os (t,p), the observed[5] Os strengths are well below the Pt and Ir

TABLE 1. Pt, Ir (t,p) Enhancement Factors and Supersymmetry Predictions

	Reaction	σ_{exp} a) (μb/sr)	ϵ_{exp} b)	$\epsilon_{s.s.}$
N = 7	^{194}Pt (t,p)^{196}Pt	366(7)	12.7(.4)	≡12.7
	^{193}Ir (t,p)^{195}Ir	347(2)	12.4(1.2)	12.3
N = 8	^{192}Pt (t,p)^{194}Pt	398(105)	12.7(1.6)	13.6
	^{191}Ir (t,p)^{193}Ir	327(3)	13.15(1.3)	13.2

a) Experimental cross sections from Pt (Ref. 5) and Ir (Ref. 6) measurements.

b) Experimental enhancement factors given by eq. 1 of Ref. 4.

c) Predictions from eq. 2,3 normalized to ^{194}Pt (t,p) experimental value.

values, possibly indicating that the expected Os-Ir-Pt supermultiplet is not being fully realized. The entire examination of Pt-Ir-Os strengths is further complicated if one tries to incorporate (p,t) results as well. Although the experimental methods in obtaining (p,t) strengths have not been as consistent as our present (t,p) measurements, there is a clear indication that the Ir (p,t) strengths[7] are far below the Pt (p,t) strengths[8] and possibly even below the Os (p,t) strengths.[9] A more consistent measurement of Pt, Ir, Os (p,t) reactions is necessary to fully understand two-neutron transfer strengths in this region.

Possibly the most unique aspect of a supersymmetry framework is that transitions between odd- and even-mass nuclei occur with the same

TABLE 2.
Low-Lying $d_{3/2}$ and $s_{1/2}$ Strengths in $^{194,196,198}Pt(\vec{t},\alpha)^{193,195,197}Ir$ [a)]

Final Nucleus	E_x (keV)	J^π	$S^{b)}$	S_{rel}	$S_{s.s.}$ [c)]
^{193}Ir	0	$3/2^+$	1.6	=1.00	=1.00
N = 7	180	$3/2^+$	0.11	0.07	0
	460	$3/2^+$	1.1	0.69	0.64
	73	$1/2^+$	0.5(3)[d)]		
^{195}Ir	0	$3/2^+$	2.1	=1.00	=1.00
N = 6	234	$(3/2^+)$	0.33	0.16	0
	287	$3/2^+$	0.49	0.23	0.60
	70	$1/2^+$	0.75		
^{197}Ir	0	$3/2^+$	3.5		
N = 5	52	$1/2^+$	1.2		

a) $Pt(\vec{t},\alpha)$ measurements of Ref. 10.

b) Spectroscopic strengths obtained in Ref. 10 using optical model parameters of Ref. 11 for $Pb(\vec{t},\alpha)$.

c) Spectroscopic strengths predicted by eq. 4. Only the predictions for $^{193,195}Ir$ are directly compared to experiment. Similar strengths would be expected for ^{197}Ir, but no low-lying $3/2^+$ state other than the ground state was populated

d) Our best attempt to obtain the $s_{1/2}$ strength from the unresolved $1/2^+ - 11/2^-$ doublet at ~79 keV in ^{193}Ir.

importance as transitions within one nucleus. To probe the single-nucleon transfer strengths, we have studied the Pt ($\vec{t}$,α) Ir reactions[10] for enriched ^{194,196,198}Pt targets using a 17 MeV polarized triton beam.

For the supersymmetry based on O(6) bosons and j = 3/2 fermions, two $J^{\pi} = 3/2^{+}$ states should be populated[1] in Pt ($\vec{t}$, α) Ir reactions, the ground state with $\sigma = N + \frac{1}{2}$ and the τ = 0 excited $3/2^{+}$ state with $\sigma = N - \frac{1}{2}$, with the ratio of the spectroscopic strengths, S,[1]

$$\frac{S(\sigma = N - 1/2)}{S(\sigma = N + 1/2)} \approx \frac{N}{N + 4} \qquad (4)$$

No other state should be populated if a single j = 3/2 orbital is responsible for the observed spectrum. The comparison between our spectroscopic strengths and the predictions based on eq. 4 is given in Table 2. Immediately one sees that ^{195}Ir and ^{197}Ir do not follow the supersymmetry predictions in that the observed distributions of $d_{3/2}$ strengths are in clear disagreement. In addition, considerable low-lying $s_{1/2}$ strength is observed. On the other hand, the distribution of spectroscopic strengths in ^{193}Ir are in good agreement with the supersymmetry predictions, both in the distribution of $d_{3/2}$ strength and the probable $s_{1/2}$ strength.

CONCLUSIONS

Based essentially on single-particle transfer measurements, we have shown that a supersymmetry structure does not apply to all Ir nuclei. However, both a good O(6) boson description for the even-A nucleus and a single j = 3/2 orbital for the odd-A nucleus are needed to realize a supersymmetry scheme. Therefore, a discussion of the validity of this new approach in this region should be restricted to ^{191,193}Ir. The realization that a dynamical supersymmetry applies to nuclei would be the first manifestation of a supersymmetry in nature. It is, therefore, important to fully establish the degree to which a breakdown of the supersymmetry in nuclei may be occurring, rather than discarding the model because it does not reproduce all possible nuclear properties.

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